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Environmental Radiation Monitoring

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Introduction

In accordance with federal regulations, Department of Energy (DOE) Orders 5400.1 and 5400.5, and Title 17, California Code of Regulations, Section 30250, LLNL monitors gamma radiation to establish radiation levels in its vicinity and to determine the direct environmental radiological impact of its operations. Gamma radiation in the environment primarily occurs naturally from terrestrial and cosmic sources. Because environmental radiological monitoring is used as one measure of the potential radiation dose the public receives as the result of LLNL operations, LLNL has developed an extensive radiological monitoring network for the Livermore site perimeter, Livermore Valley, Site 300 perimeter, and nearby off-site locations. Gamma radiation has been measured at the Livermore site since 1973, and the environmental radiation monitoring program was implemented at Site 300 in 1988. The absorbed gamma radiation dose imparted to thermoluminescent dosimeters (TLDs) is the result of TLD exposure from both terrestrial and cosmic radiation sources as well as LLNL sources, if any.

Cosmic Radiation Component

Gamma radiation in air is produced by the interaction of cosmic rays, which contain high-energy particles and emanate primarily from beyond the solar system, with atmospheric nuclei. The cosmic radiation component accounts for about half the observed site annual average gamma radiation.

Terrestrial Radiation Component

The elemental composition of the terrestrial gamma radiation component is primarily due to naturally occurring isotopes of the uranium, thorium, and actinium decay series present in soil worldwide that produce gamma radiation during radioactive decay. The concentration variability of the primordial nuclides found among soils is determined by the ratio of thorium-232 to uranium-238 ($^{232}Th / ^{238}U$) present in these

regions at the time of the earth's formation over four billion years ago and ranges from 3 to 4 around the world. Characterizing the natural background enables LLNL's monitoring effort to determine whether or not there is a contribution from LLNL operational effluents, if any.

General Methods

TLDs are deployed in the field to assess the environmental impact of laboratory operations at both the Livermore site and Site 300. This is done by comparing the gamma radiation data acquired from the LLNL perimeter site locations to various locations monitored in the Livermore valley, and gamma radiation data from Site 300 perimeter locations to locations in Tracy and near Site 300.

As previously mentioned, the variability of the naturally occurring radioisotopes present in the soil due to geological formations becomes the largest contributor. Additionally, the meteorological conditions present also contribute to seasonal variability.

Deployment of the TLDs is done following the annealing process at the beginning of each quarter of the year. The retrieval of the TLDs is done as near to the end of the quarter as possible in order to have a 90-day exposure period. All data are normalized to a 90-day standard quarter basis in order to make valid comparisons.

Details of the TLD calculations and reporting of external gamma radiation dose are described in ORAD EMP-TLD-CALC.

Monitoring Locations

In 1998, external doses from gamma radiation were monitored at 14 Livermore site perimeter locations (shown in **Figure 12-1**) and 23 Livermore Valley locations (**Figure 12-2**), which are used for background comparison to perimeter location data. Similarly, gamma doses are monitored at nine perimeter-monitoring locations at Site 300 (**Figure 12-3**). Additionally, five off-site locations, which are located near Site 300, and two locations in nearby Tracy were monitored. Summary dose calculations for all gamma-monitoring locations are presented in **Table 12-1**.

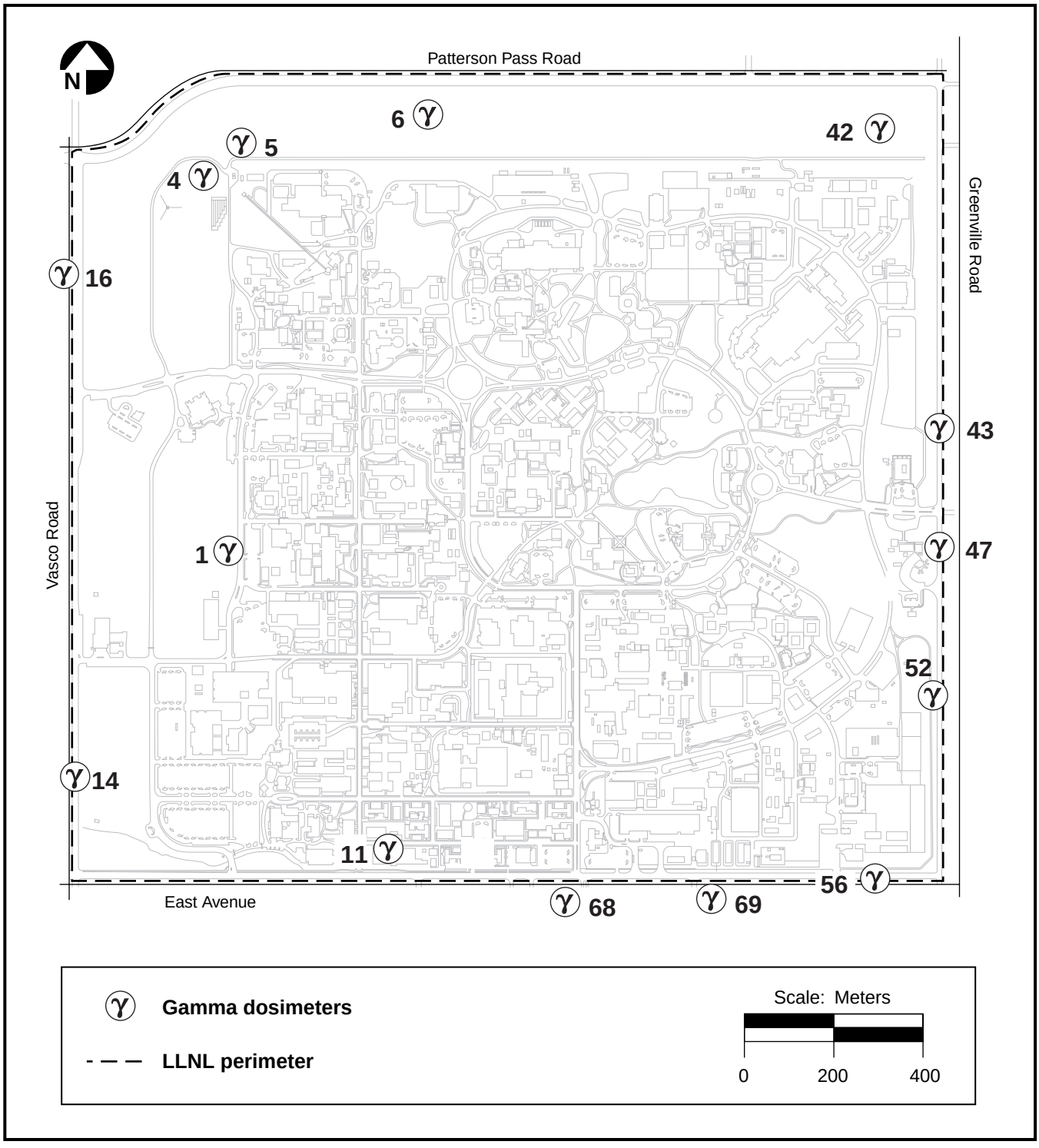

Figure 12-1. Gamma dosimeter locations, Livermore site, 1998.

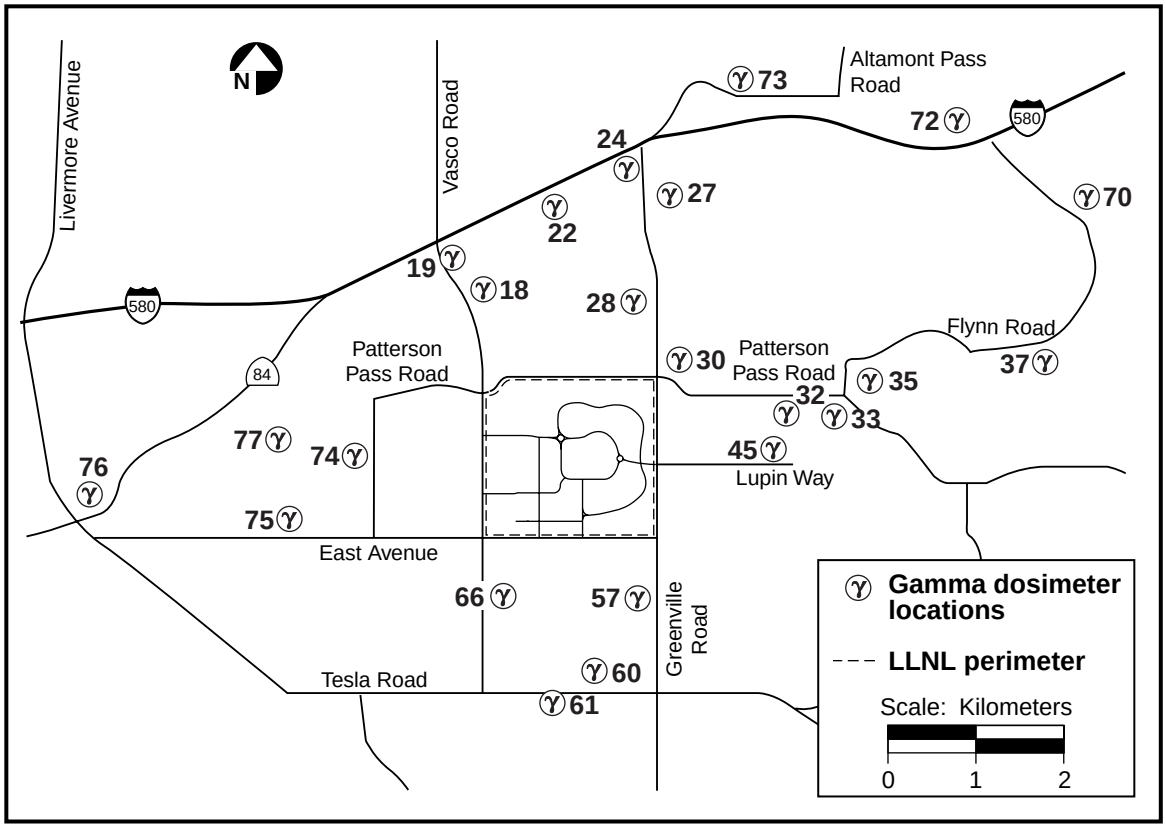

Figure 12-2. Gamma dosimeter locations, Livermore Valley, 1998.

Collocated Monitoring Locations

The State of California Department of Health Services (CDHS) Radiological Health Branch (RHB) performs routine independent gamma monitoring at several sites collocated with LLNL's TLD network. RHB site locations correspond to several LLNL perimeter, valley, Site 300, and off-site locations. Although RHB has been comonitoring these locations for several years, they have added sites to their network and continued to monitor at one LLNL perimeter location that was discontinued in LLNL's TLD monitoring network in 1995. This location, which lies approximately halfway between site 14 and site 16 on the Vasco Road perimeter, was formerly designated as a valley site location in 1994 although it actually is located just outside the LLNL perimeter at Vasco Road and the Mesquite Way perimeter entrance. The nine locations monitored by CDHS-RHB are LLNL-15, -19, -28, -47, -75, -78, -91, -96, and -99. RHB added location LLNL-47 to their network in the third quarter of 1998. (See **Figures 12-1**, **12-2**, and **12-3** for these corresponding locations.

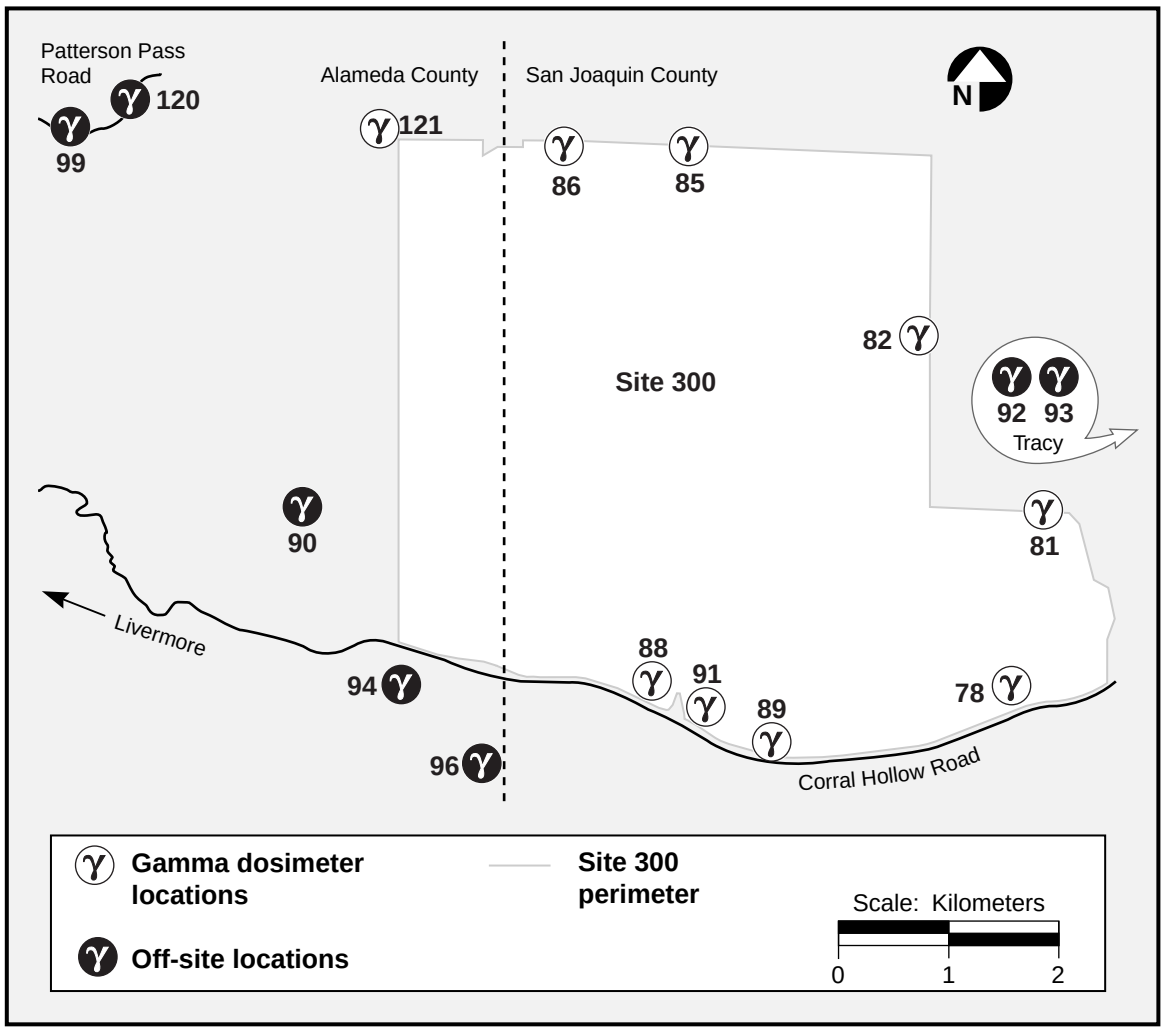

Figure 12-3. Gamma dosimeter locations, Site 300 and vicinity, 1998.

Results of Gamma Monitoring

Gamma doses for the Livermore site perimeter, Livermore Valley, and Site 300 from 1988 through 1998 are shown in **Figure 12-5**. Beginning in 1995, all of the quarterly gamma radiation data points were normalized to standard 90-day quarters, as is the practice of the Nuclear Regulatory Commission (NRC) (Struckmeyer 1994). When the data are corrected to standard quarters to normalize the data to the same number of days deployed, the variability due to exposure duration is reduced.

Livermore Site

Table 12-1 presents a summary of the quarterly and annual TLD gamma radiation dose equivalents for the Livermore site perimeter locations and Livermore Valley off-site locations. The mean 1998 dose equivalent from external direct radiation exposure at the Livermore site perimeter, 0.597 mSv, is statistically the same as background external dose measured in the Livermore Valley, 0.597 mSv. **Table 12-2** lists the yearly doses due to direct gamma radiation at the LLNL site perimeter. All doses fall within the predicted range for background radiation, and no LLNL operational impacts are discernible.

Table 12-1. Summary of dose calculations for gamma-monitoring locations at all sites in 1998 (in mSv).[a]

Quarter	Location									
	Livermore site		Livermore Valley		Site 300		Tracy		Near Site 300	
	Mean	2 SE[b]	Mean	2 SE[b]	Mean	2 SE[b]	Mean	2 SE[b]	Mean	2 SE[b]
First	0.141	0.005	0.142	0.008	0.177	0.011	0.160	0.023	0.177	0.017
Second	0.148	0.006	0.147	0.007	0.176	0.013	0.152	0.020	0.192	0.032
Third	0.147	0.007	0.145	0.008	0.177	0.012	0.153	0.024	0.195	0.027
Fourth	0.160	0.006	0.159	0.008	0.191	0.013	0.175	0.006	0.209	0.029
Total[c]	**0.597**	**0.024**	**0.597**	**0.027**	**0.718**	**0.041**	**0.640**	**0.073**	**0.775**	**0.106**

a 1 mSv = 100 mrem.

b SE = Standard Error (standard deviation of the mean).

c Annual totals, which account for missing data by averaging data for each site (see Data Supplement).

Table 12-2. Annual dose by year at the Livermore site perimeter due to direct gamma radiation.[a]

Year	mSv	mrem
1988	0.59	59
1989	0.58	58
1990	0.58	58
1991	0.56	56
1992	0.56	56
1993	0.57	57
1994	0.56	56
1995	0.56	56
1996	0.55	55
1997	0.59	59
1998	0.60	60

a Data normalized to standard 90 days per quarter (360 days per year).

Collocated Sites

A convenient means by which a valid comparison for the collocated sites can be made is based on an annual average dose rate at that given site location. Although RHB does not deploy and retrieve their TLDs on the same days as LLNL, RHB does normalize their data similarly to a standard quarter of 91 days. The dose rate measured by RHB at each monitoring location is normalized to the LLNL 90-day standard quarter (i.e., LLNL's 90 day vs. RHB's 91 day) and compared to LLNL location data converted to an annual average dose rate. These results are depicted for each collocated monitoring site in **Figure 12-4** below reported in dose rate units of μGy / h, where 1 μGy = 100 μR. Although LLNL-15 is no longer monitored, LLNL-14 located approximately 1 / 4 mile south is substituted in lieu of LLNL-15 for comparison.

When the data are combined together to formulate a combined location annual average, the two data sets are easily compared within 1 standard error of the combined annual mean absorbed dose rate. The standard error is calculated as the standard deviation (σ) of the combined data set (i.e., CDHS and LLNL) divided by the square root of the

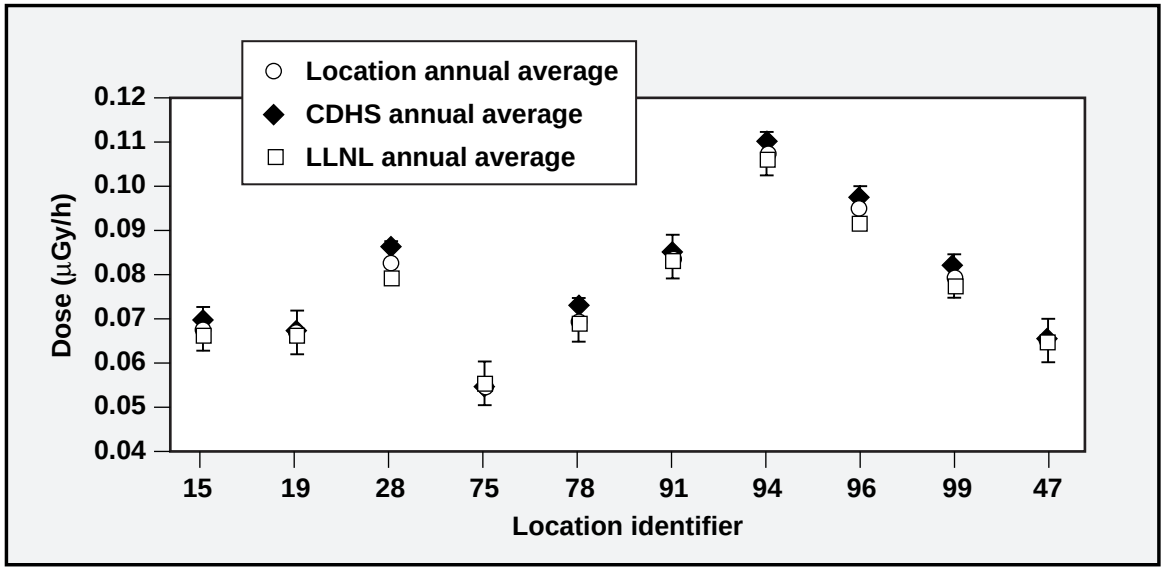

Figure 12-4. Comparison of gamma dose rates measured by CDHS-RHB and LLNL TLDs at several LLNL perimeter, Livermore Valley, Site 300, and off-site locations. TLD absorbed dose rates are compared by location error bars spanning one standard deviation of the combined RHB and LLNL annual mean. Locations are shown in **Figures 12-1** and **12-3**.

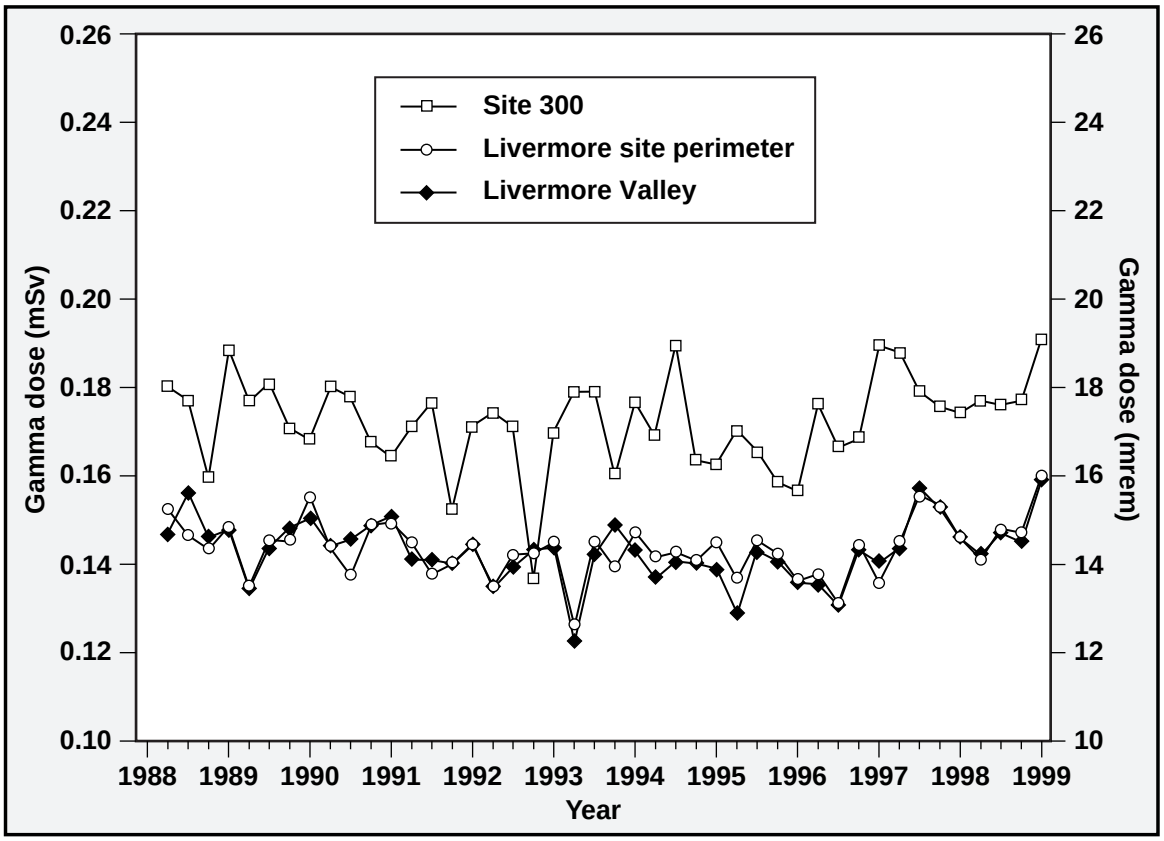

Figure 12-5. Quarterly gamma dose measurements at the Livermore site perimeter, Livermore Valley, and Site 300, 1988 to 1998.

number of data combined to create the data set (n). Thus, the formula representing standard error of the combined mean is $\sigma / \sqrt{n}$. Although slightly elevated RHB data are depicted in **Figure 12-4**, which may be attributed to an uncorrected transit exposure, the variance is insignificant relevant to the combined annual average data.

Site 300

As seen in **Table 12-1**, the measured Site 300 perimeter annual average dose in 1998 was 0.718 mSv, the measured dose at the off-site locations near Site 300 was 0.775 mSv, and the measured doses in and near Tracy were 0.640 mSv. All doses are within the predicted range for background radiation, and no LLNL operational impacts are discernible.

At Site 300, the initial TLD network design limited monitoring to the Site 300 perimeter and two locations in and near the city of Tracy, which were chosen to represent background radiation levels. However, the region around Site 300 has higher levels of naturally occurring uranium, present in the Neroly Formation. The mean dose measured in the off-site locations of the area around Site 300, which is used to represent the high end of background radiation from this formation, was 0.775 mSv and is greater than the Site 300 perimeter dose of 0.718 mSv. The Tracy area, with a dose of 0.640 mSv, is underlain by a geological substrate composed of alluvial deposits of clays, sands, and silts overlying bedrock. The difference in doses can be directly attributed to the difference in geologic substrates.

The doses at the Livermore site perimeter and in the Livermore Valley are comparable from 1988 to 1998. However, while Site 300 doses are similarly comparable, TLDs continue to record slightly higher direct gamma doses than the Livermore site and the Livermore Valley, which is expected given the differences in geology between these sites.

Environmental Impact

Based on past measurements (Lindeken et al. 1973), terrestrial radiation doses in the Livermore Valley vary from 0.25 to 0.60 mSv/y. Cosmic radiation, as calculated for the local elevation and geomagnetic latitude according to the data of Lowder and Beck (1966), is about 0.35 mSv/y. This combination results in a typical total direct radiation dose level of 0.6 to 0.7 mSv/y; however, local geological and meteorological factors will impact these dose levels. Direct radiation doses measured at the Livermore site perimeter in 1998 are near these predicted values and are statistically equivalent to the Livermore Valley doses, which are considered natural background levels. This indicates that any dose from LLNL operations is not large enough to be seen within the wide range of natural variation in background levels of these different locations.